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ABSTRACT

Most conventional school science curricula and the teaching practices that implement them offer students no firsthand contact with working science. This paper seeks to answer the following questions: (1) How can "school science" claim to offer a basis for education in or about science at all? (2) What is the status of this claim in relation to contemporary scholarship about the nature of science and to reasonable alternative approaches to science education? (PR)

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THE MISSING CONTEXT IN SCIENCE EDUCATION:

SCIENCE

J. L. Lemke

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THE MISSING CONTEXT IN SCIENCE EDUCATION: SCIENCE

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Where's the SCIENCE?

Most conventional school science curricula and the teaching practices that implement them offer students no firsthand contact with working science. Most students, in the course of ten or more years of what is called "science education" in school, never meet a scientist, never observe science being done in the laboratory or the workplace, never see samples of professional scientific or technical writing, never hear the language of science in use for its normal social functions, never come into contact with the equipment, processes, practices, and social and economic realities of science as a human activity.

The entire context of science as it is used in daily practice by men and women from every social, cultural, national, ethnic, and racial group, for all the purposes for which it is used and practiced in our society is missing from conventional science education in schools.

How then can "school science" claim to offer a basis for education in or about *science* at all? What is the status of this claim in relation to contemporary scholarship about the nature of science and to reasonable alternative approaches to science education? These are the key questions I would like to briefly consider in this paper.

Simulations and Simulacra

What students do encounter in conventional school science courses are mainly simulations and simulacra of science.

They encounter simulacra of the subjects and objects of science: science teachers in place of working scientists and technologists, textbook discourse in place of the spoken and written language of working science, "school science" topics and information in place of those which might actually occur in any actual context of use or practice of science, school laboratory and demonstration equipment in place of the actual technologies in use everywhere else in our society.

They encounter simulations of science as a process or activity: school laboratory exercises in place of professional investigative practices;

SE 053 838

efforts to solve problems that have no real contexts, no real parameters, no realistic complications; study of examples that are idealized, oversimplified, decontextualized.

Science curricula present materials and experiences whose only connections to working science are by way of a lengthy chain of abstract similarities which can only be constructed *backwards*, retrospectively from ultimate familiarity with working science itself -- a familiarity only a handful of students ever finally obtain.

How is a science textbook like professional scientific and technical writing? How is it different? How does learning to use a science textbook prepare students to use any other written genre of science? How can students construct the similarities, the bridges between these very different objects unless we teach them how to do so? And how can we do that if students are never given any firsthand contact with real scientific writing? (For some bases of comparison between the written and spoken language of school science vs research science, see Lemke 1989, 1990a, 1990b; Bazerman 1988)

How is a science lab and the activities that go on in it like a working scientific laboratory and the activities that go on it in? Here the similarities are at an even higher level of abstraction, requiring of students an even more formidable "transfer" of learning from one context of use to another. How can we conceivably expect students to be able to do this without instruction, without being taught just how what they do is like and also unlike professional science and technical work? And how can we teach this without giving students some direct, firsthand familiarity with working science?

Science, Abstraction, and Transfer

Science education is built upon a set of theoretical and philosophical beliefs about the nature of science and the nature of learning which are not reliable in practice.

Science education traditionally defines science as a body of knowledge, beginning with facts, and moving on to concepts and relations, models and theories, processes and activities. Its conception of knowledge is a fundamentally mentalistic and superficially cognitive one. What is known, be it facts or concepts, is said to be known in the "mind" (a curiously unscientific place, both immaterial and inaccessible to observation). The processes of science are likewise reduced to imaginary "mental" or "cognitive" processes, which also occur only in this imaginary domain. Traditional science education argues that the same mind-knowledge and the same mind-processes take place both in the school context and the context of working science, and that it is these which constitute *science* and these which are being taught.

This is no longer a credible view, neither of science nor of learning to do science. *Science* is neither a system of well-understood mental

concepts and processes, nor a body of facts, principles, and theories. These are at best the tools, and in some cases, the products of scientific activity. Science is a social subculture: a vast interlocking network of the working activities of producers and users of these products and tools (cf. Latour 1987, 1988). A culture and its activities cannot be known by inference from a study of its products and tools alone, but only by direct knowledge of their actual contexts of production and use.

Science is a complex of specific, situated human social and cultural activities. It cannot even be adequately conceptualized merely as "what scientists do" since scientists as such can only be defined by their participation in these activities, by their place in a network of relations and transactions which includes many we would not call scientists, as well as other critical participants which are neither necessarily human, nor even animate. For all these, their entire material being, brains and bodies, participates. Each event, each transaction is unique, uniquely dependent on the specificity of context of situation. We are taught by our community to construe certain patterns of similarities, certain meaningful relationships, among these events according to the discourses and practices of a particular culture and subculture. We view these networks of activities, and we participate in them, according to how we have learned to make sense of them.

What we learn are systems of resources, such as language, gesture, depiction, symbolic representation, and the meanings of actions generally. We learn how to deploy these resources in patterns that are meaningful to other members of our communities: scientific discourses, appropriate gestures, technical diagrams, mathematical and chemical formulas, measurement procedures. In doing these things we use our brains, and the whole of our bodies, and we do so in inextricable interaction with our material environments. If it is useful to formulate a notion such as cognition at all, we must never forget that cognition, the act of making meaning, is always a bodily and interactive process, dependent on tools, on environmental affordances and feedback (re-afference), on situational context, and most profoundly on internalized patterns of originally external, and especially social, culturally and symbolically mediated, interaction. It is this "interactivity" in and through which we live, make sense of and to others and the world, learn, and do science.

This view of learning and meaning, and of the role of social interaction and cultural resource systems in it, has been developed over many years in psychology (e.g. von Uexkull 1926, Gibson 1979, Bateson 1972, Vygotsky 1978, Luria 1976, Leontiev 1978, Piaget 1971, Cole 1990, Bruner 1983, Harre 1991), in anthropology (e.g. Malinowksi 1935; Bateson 1958; Levi-Strauss 1963; Geertz 1973, 1983), in social linguistics (Bakhtin 1981, Voloshinov 1986, Halliday 1978, Hymes 1972), and social theory (Foucault 1966, 1969; Bourdieu 1972; Giddens 1984). It is profoundly anti-positivistic: it denies that reality is self-presenting, that the meaning or sense of the world is given to us or inherent in it, that science only re-presents it. It is more comfort-

able with the philosophical positions on the modern spectrum from phenomenology (e.g. Husserl 1960, Merleau-Ponty 1962, Schutz 1967, Ricoeur 1981) to constructivism (e.g. Vico 1968, Berger & Luckmann 1971, von Glasersfeld 1987) and social semiotics (e.g. Halliday 1978; Lemke 1984, 1990b; Kress & Hodge 1988; Thibault 1991) which hold that primary experience has cultural categories imposed upon it, and that our knowledge is always made in inter-activity. (For the beginnings of a theoretical synthesis of cultural-semiotic views of meaning and material-ecological views of process and context, see Lemke in press.)

In this view, similarities are *constructed*, they are *made*, according to the dispositions of our culture and subculture (and within that our personal trajectories of culture-mediated experience). Concepts are embodied in language-using practices, which are in turn embedded in larger structures of social activity (for a view of what happens in science classrooms in these terms, see Lemke 1990b). Abstractions are *abstracted* from sets of experiences and name the practices by which we construct the similarities among all the instances to which an abstract category applies. How is *heat* like *sound*? *light* like *magnetism*? The *concept* of energy is not a single anything; it is a whole system of disparate but linked practices, ways of talking, ways of measuring, ways of calculating, ways of *seeing*. To learn this concept is to learn how to apply it in ever-widening circles of practical contexts, to learn how exactly our culture, our historical scientific tradition, constructs connections between this situation and that, that and the next.

You cannot "grasp" a concept like energy; to teach that you can is to promote an intellectually and socially dangerous illusion. You can construct a higher-order pattern, a pattern in the strategies by which our culture connects situations of different types, but this will not enable you to anticipate how the concept of energy will apply to a totally new situation -- or even whether or not it can usefully be made to. Historically, and in the intellectual recapitulation of culture that grounds the educational process, it has always taken new work, new insight, new ways of constructing new kinds of connections to apply the concept of energy to new domains. In each successful instance the concept of energy itself was changed, was extended.

The same is true for all abstractions, all concepts, all categories, but especially for the most abstract ones, those that apply to the most superficially dissimilar instances. They are not singular, not unitary. The "concept" is not the same in any real sense from one situation to another very different one: to use the concept we must do very different things, use different discourses and construct different semantic patterns in language, draw different diagrams, perform different manipulations of objects. That we have a "concept" merely means that we ALSO have ANOTHER set of procedures for connecting what we do in one case with what we did in the other.

This means that the similarities on which abstract concepts are based are not "there" for all to see. Either they are entirely cultural constructions, or even if not, the ones on which a particular concept is

based are indistinguishable from the infinite other possible similarities that may be construed between any two objects, until we are taught how to attend to, pick out, and/or construe the ones our culture, our physics wants us to see. Consequently, there is no reason to expect "transfer of learning" from one situation type to another. We must be taught, separately in each case, how to apply "a concept" to that case. In fact, we must be taught two things: how to operate in the new context, *and* how to construct a conventional similarity between that operation-in-context and all the others to which our culture gives the same name. (An interesting science classroom example of how students have to learn to re-see and re-name what science says is right before their eyes is analyzed in Lemke 1990b: 144-147).>

For a long time now, academic education has based its claim to practical value on the principle that abstract concepts, learned in school contexts, would transfer to non-school contexts because of the inherent applicability of the abstract concepts themselves to a wide variety of situations. There is no credible empirical evidence for this claim whatsoever. The applicability of abstract concepts across contexts is a *retroactive* social construction; it only works *after* you know how to make it appear to work. It is, of course, easiest to make it appear to work in cases where the contexts do not significantly differ in TYPE, but only in details which the experimental subject has already been taught to classify in the same way. As soon as we leave the laboratory and examine natural and uncontrived contexts, we find that not even the simplest abstract principles of arithmetic are applied unchanged from context to context, nor is there any significant transfer of learning from school contexts to everyday activity (see the excellent review and critique in Lave 1988). One can note a very exact similarity with the problem of how scientists need to work to contrive the transfer of their theories' applicability from the laboratory context to any other (see Latour's 1987, 1988 analysis of this in his study of Pasteur and of contemporary science).

Every teacher who has ever posed a truly novel problem for her students, or observed them outside the classroom context, will know how rare evidence for transfer really is. Students confronting a novel situation usually simply do not know where to begin. They do not know *which* of the concepts they have learned may be applicable. Why should they? This applicability is not a fact of nature, it is a social construction, and it must be learned, or re-invented, not "seen" or "discovered". When students do guess the applicable concept, it is usually because it is one they have just been studying; otherwise they wouldn't have a clue, since the situation, the problem itself does not provide such clues (at least not in the form of abstractions, until we have learned how to see it in those terms; practical situations do, however, provide a host of other ways in which they shape our interactions with them, cf. Lave 1988).

Of course students do independently construct some kinds of similarities between situations on their own. These may agree with those constructed by the discourses and practices of science or they may not. The odds are not in the students' favor. When students do ef-

fectively and more or less independently recapitulate the history of modern European science, it is largely because they are so positioned within contemporary society that they have already begun to construct some of the higher-order patterns that characterize how our dominant cultural tradition approaches certain kinds of problems. This will be much more commonly the case for students of upper-middle class cultural background than for students who are not daily immersed in the dominant subculture of our society, the one that dictates the curriculum. It is not evidence of superior intelligence, but of privileged cultural, social, and gender positioning.

Classroom, Clinic, Computer

What should an education in science be that is both an education about science and a scientific education for life and work beyond school?

It cannot be limited to the discussion of abstract concepts in classrooms, however many idealized examples are provided. It cannot be limited to experiences of the processes of science divorced from the research and work contexts in which those processes have their meaningful functions. It cannot, in short, be limited to classrooms and school science laboratories at all. Students' knowledge of science cannot come solely from textbooks and science teachers, nor from experiences solely in the school context, if it is to be knowledge that will be applicable beyond the school.

Classroom education is not the only model of systematic learning for practice in our culture. Medical education, one of the most significant branches of science education for practice, has always insisted on retaining a *clinical* component, where students observe, interact with, and participate in clinical medicine, with practicing physicians, in functioning hospitals. In other parts of the world, medical education may begin immediately after completion of secondary school, and in some medical education programs there is an effort to begin clinical study simultaneously with classroom and laboratory work. There is an antagonism in medical education between the clinical and the academic models; they do not combine easily in mutually supportive ways. The academic model asserts the superiority and particulary the priority of theory over and before practice. The clinical model insists that theory is a mere tool in the arsenal of medical practice, one among many, given meaning and relevance by its contexts of use, not determining those contexts *a priori*.

Science education also has its tradition of "field trips" and "field study", but the former are too often only visits to sites like museums which again display only the results or provide only opportunity to simulate the processes of science, and the latter are confined to observations of nature, or more rarely, of technology, again as if on display and not as elements of working scientific and technical activity seen from the viewpoint those doing the work. Field trips are generally rare, and considered expensive and inconvenient luxuries.

Science is in use pervasively in our society. It is in use in the basement of the school building where the building engineer or custodian works with the heating system, the plumbing, the ventilation and air-conditioning, the electrical circuits that serve the building. It is in use behind the scenes at the museum in work on preservation and restoration, preparation of exhibits, and scientific research. It is in use at the local power plant, the local sewage treatment works, solid waste recycling center, transit system, auto repair shop, medical clinic, pharmacy, manufacturing plant, agricultural station. Science as an activity of our society is not happening when students walk through a park or nature preserve gathering samples and making observations; that is simulation of science. It is happening in the offices of the parks department where plans are made for the maintenance and development of the park's flora, fauna, and facilities, and in the activities which carry out these plans.

Science as a total system of social activities is not merely research science, it includes all the uses of scientific practices in the workplace, in the home, in the environment. It is science as science is done and used by those who are trained to use it according to the norms of our society. It is these practices and norms that students need at least to learn about, at least to connect with what they do in classrooms and school science laboratories. Ultimately it is these practices from which students can begin to grasp the higher-order, implicit cultural patterns that our community construes as "thinking" and "doing" *scientifically* in any context of situation. School contexts are far too limited in their diversity, and far too little connected in the curriculum to non-school contexts, to form an adequate basis for this ultimate outcome of science education.

There are two common objections to making science education more clinically based. One is that students need concepts *first* before they will be able to make sense of real world scientific and technological practice. That is simply wrong, a misconception of the nature of abstract concepts and their relation to instances. The other is that it is simply not *practical* to take large numbers of younger age students out of school and into the world the rest of us live in on a regular basis. What is actually meant, here, I think, is that adults, particularly middle-aged, upper-middle class men, do not want children around them. The presence of the young in the workplace, as until very recently the presence of women, is taken to degrade the status of what goes on there. Our society needs to come to terms with the ghettoization of younger citizens, and with the resulting infantilization of their behavior, creating a self-fulfilling prophecy of the irresponsibility of the young.

By and large, the norms of middle-class culture do not expect people under the age of about 18 to do any productive labor in society, or to take responsibility for anything seriously important to older members. This dominant cultural view, and its institutionalization in labor laws written to benefit the interests of older working-class men, has led to the remarkable infantilization of adolescent behavior in our culture as compared to many others around the world and in other peri-

ods of history. We appeal to this effect to justify the denial of legal, political and property rights to younger citizens, as well as to deny them access to the workplace, except occasionally as tourists. Schools have become the institutions which keep the young out of the mainstream of social life, and the culture of schooling denies to the young the opportunity to learn the normal practices of our society, among them the ones we call science.

Certainly from the age of biological maturity (13 at the most today), there is no scientific reason why any person should not be able to learn and perform a wide range of socially valuable skills and tasks, or participate, in some meaningful way, in any social practice in our society. Such participation could and should be the fundamental basis for education and learning, in science, and in other spheres of social life.

Classroom education may still have an important role to play. Especially for the youngest students, but even for those who are already full participants in adult society, the classroom can provide a time for reflection, for abstraction, for analysis of practice, for consideration of alternatives, for theory. Theory may be used in practice, but it is rarely itself an object of concern in practice (except in the practice of theory-builders, who are few). *Praxis*, that ideal dialectical interplay between theory and practice, which is the basis for critical, reflective action, can arise neither in the classroom nor in the exigencies of direct practice, but only in the relation between them. Of course, classrooms are not the only social arrangements for gaining theoretical perspective on practice, but they are one that already exists.

The classroom model of education is likely, in fact, to very soon be caught in a squeeze that may end its useful lifetime of a century or two. On the one hand the demands of the workplace for relevant skills will increase pressure on schools to provide what they cannot: contexts in which such skills can be developed in ways that will effectively transfer to the workplace. On the other hand, new ways of providing access to basic information and to the discourses that make sense of that information (what schools do now provide, cf. Lemke 1990b) are about to revolutionize people's educational options.

Increasingly, all socially valuable information is being stored in digital form on computers. New information technologies are making it relatively easy for anyone with certain basic skills to access whatever information they need. At the same time, computer software development is moving toward more and more effective tutorial aids, and future prospects seem good that adequate support will soon be available for people to learn independently of real-time access to experts (or teachers, see for example Lemke 1993 and references therein). When the paradigm of independent learning is combined with the context of full participation in adult social life, the role of and need for schools as such, and certainly for a pervasive model of classroom instruction and curriculum-dictated education, may be hard to justify, intellectually, practically, or economically.

In a future economy of distributed intellectual, managerial, and technical work, where what many people get paid for is the production and transformation of information, the actual social practices of work will be very like the actual practices of independent learning with on-line information technologies and tutorial applications. The boundary between learning and working will tend to disappear altogether. That does not seem to leave much room for schools, except perhaps for the very youngest students. Where schools today provide important functions, such as social interaction around themes and issues, other solutions can easily be found in the brave new context of the future I am trying to foresee.

A very wise man once said that we learn by doing. I do not know if he meant that we learn only what we actually do, but that is what I believe, and I believe that that is how students will learn science in the future. Surely they are not doing that today. The missing context in science education today is not just science; it is, in sorry fact, successful education itself. I believe that our society will not tolerate this condition very much longer, and that if it needs to move beyond schooling as its primary mode of education, it will rapidly and ruthlessly do so. Researchers in the field of education would do well to turn their attention now to the problems of integrating school-based, clinical, and computer-mediated independent education -- and very soon to the problems of the new post-scholastic education of our future.

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